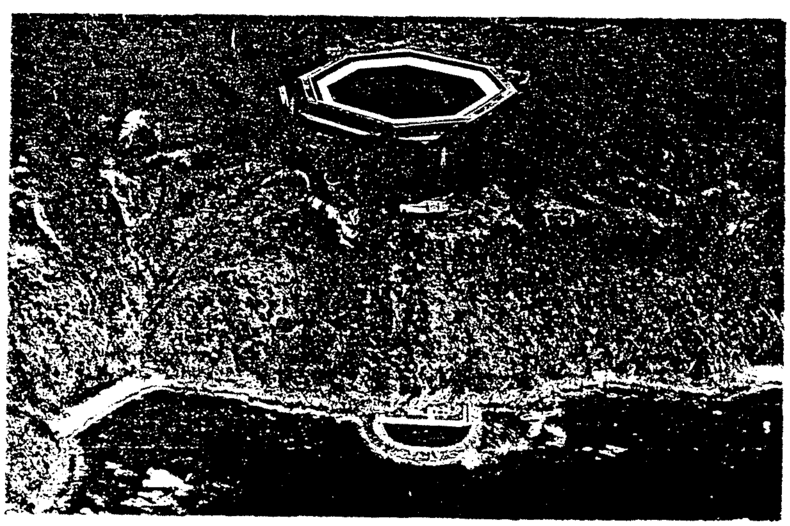
Demonstration Test of Seawater Pumped-Storage Power Plant

INTRODUCTION

The concept of seawater pumped-storage power generation, using the sea as the lower reservoir, is considered to be effective for Japan, as the country is surrounded by the sea and has steeply sloped coastlines. The Ministry of International Trade and Industry (MITI) has been conducting surveys of suitable sites for such a project since around 1960. However this type of power generation has not been developed as yet, since various technological and environmental problems arising from the use of seawater have not been resolved.

Electric Power Development Co., Ltd. (EPDC), under commission from MITI, had, since 1981, been conducting preliminary studies and feasibility, surveys concerning seawater pumped-storage power generation in Okinawa Prefecture as the object of investigation till 1989. As a result, EPDC had been able to identify most of individual technical problems involved. In 1990, EPDC began construction of this plant in Okinawa.

The plant is being constructed at Churasaku in the Kunigami village, on the Pacific coast of northern Okinawa Island, at the southern, end of the Japan archipelago. (See picture 1 & Figure 1)



Picture 1 Image Picture of the plant

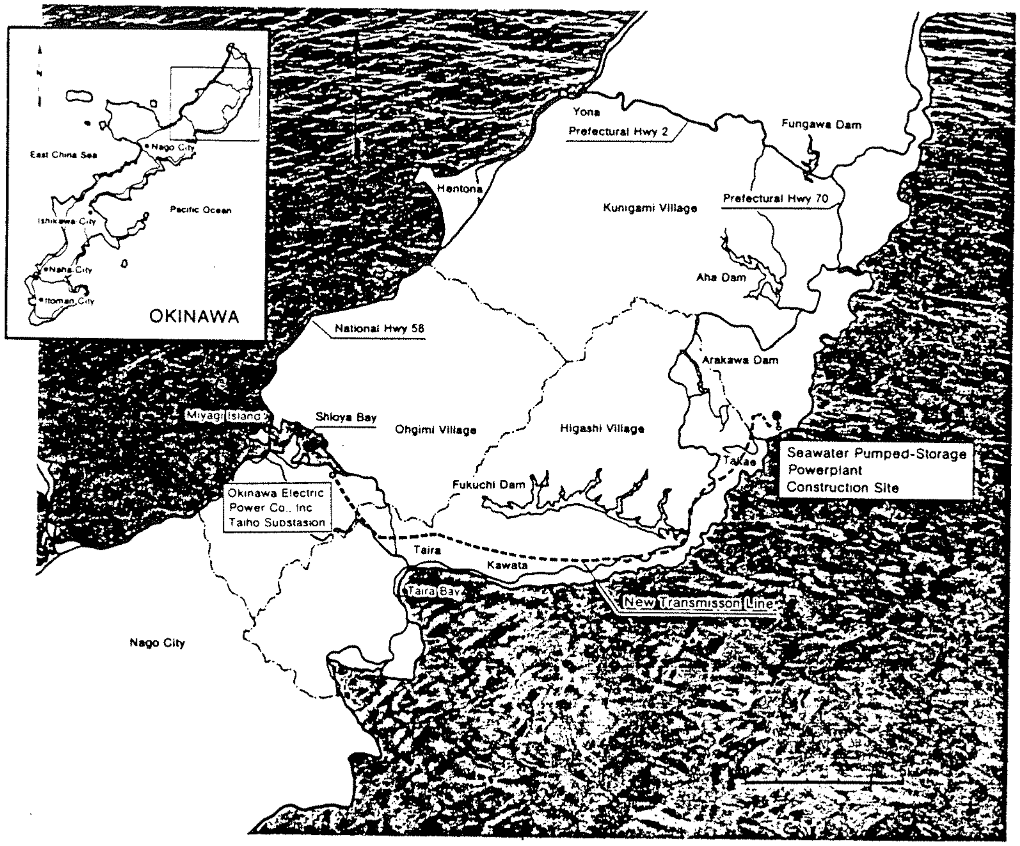


Figure 1 Location of the Plant

PURPOSE OF TEST

Pumped-storage electrical power generation is an efficient way in achieving optimal use from existing thermal and nuclear power generating plants.

Since Japan is surrounded by water, favorable geographical conditions exist for seawater pumped-storage power plants. Investigation and research of the phenomenon has been ongoing for a long time.

Before such power plants can be put to practical use, the concepts must be proven through extensive testing. MITI conducted six years of technical and environmental investigations in seawater pumped-storage power generation beginning in 1981. In 1987, MITI decided to start construction on a demonstration model plant. The plant has an output capacity of

30 megawatts and is unique as the worlds first seawater pumped-storage power generation facility.

This demonstration test is a government initiative undertaken by EPDC.

WHAT IS A SEAWATER PUMPED-STORAGE POWER PLANT?

Seawater pumped-storage power plants have several advantages over fresh-water pumped-storage power plants in current use. Costs for dam construction are lower since the sea is used as the lower reservoir. Furthermore, power transmission can be more efficient since the power plants can be built near electric power consumption areas. However, several technical and environmental concerns caused by using seawater will have to be solved.

Metal corrosion and marine organism growth is accelerated in seawater as compared to freshwater requiring the development of new technology.

Since seawater will be pumped to the upper reservoir, the environment will have to be protected from seawater seepage and spray caused by strong winds.

OUTLINE OF THE PROJECT

EPDC, under commission from MITI, has been making basic studies for resolving the problems peculiar to a seawater pumped-storage power project and of the measure to be taken.

As a result, an approximate outlook regarding the measures to be taken against the individual problems anticipated was obtained. As the next stage, it was decided that a comprehensive and long-term verification should be made by constructing a plant of real scale and carrying out trial operation. (See Figure 2.3, Table 1)

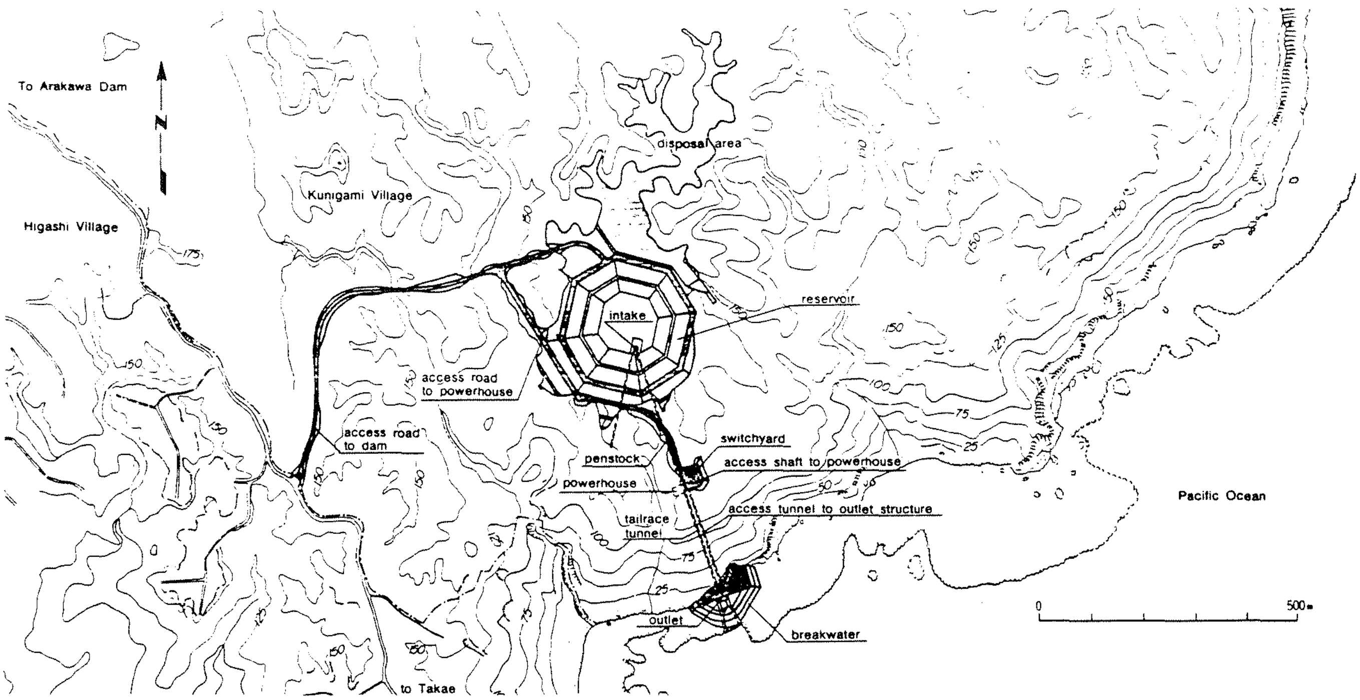


Figure 2 Plan of the Plant

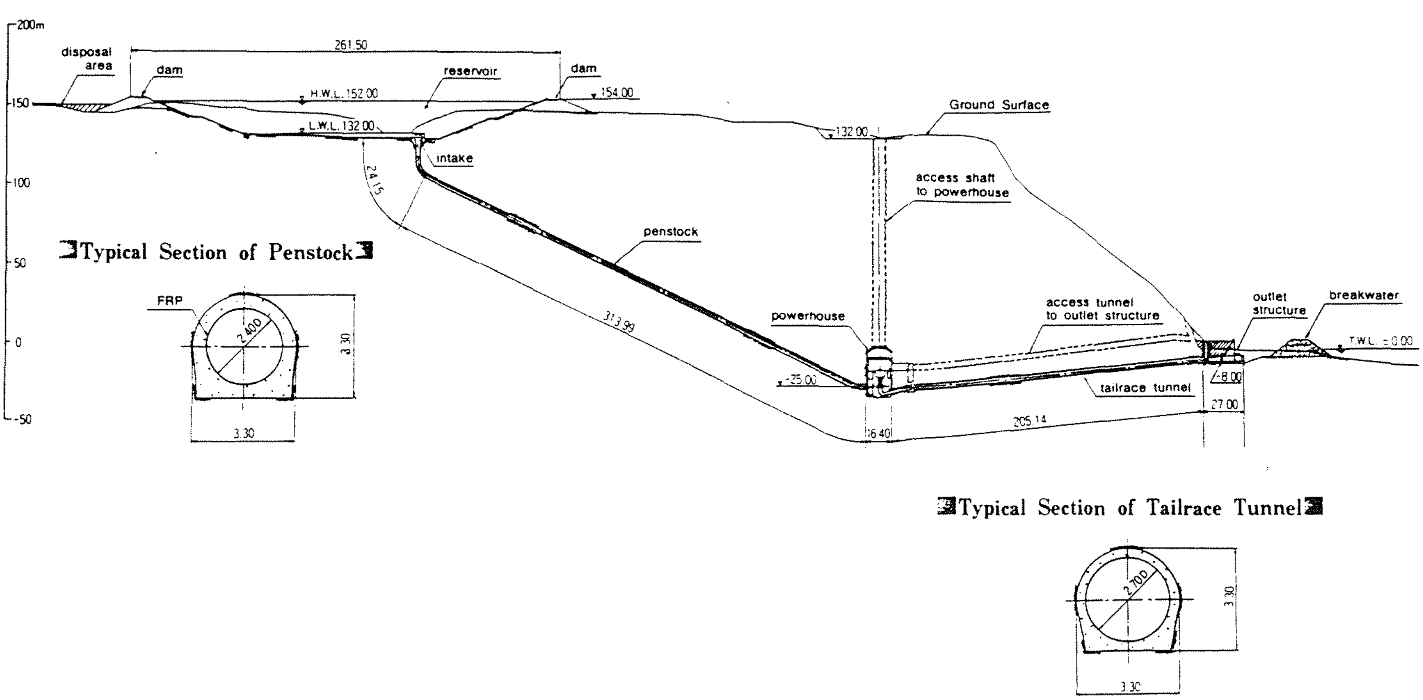


Figure 3 Profile of the Plant

Table 1 Specifications of the Plant

ITEM	UNIT	DATA
Regulating Reservoir		
High Water Level	m	152
Low Water Level	m	132
Available Drawdown	m	20
Water Surface Area	km^2	0.05
Gross Storage capacity	10^6m^3	0.59
Effective Storage Capacity	10^6m^3	0.56
Type		excavated type (Rubber Sheet Lining)
Dam		
Type	-	Filldam with Facing (Rubber Sheet Lining)
Height	m	25
Crest Length	m	848
Volume	10^3m^3	360
Waterway		
Penstock (Inside Dia. x Length)	m x m	2.4 x 314
Tailrace Tunnel (Inside Dia. x Length)	m x m	2.7 x 205
Power Generating Scheme		
Normal Headwater Level	m	149
Normal Tailwater Level	m	0
Normal Effective Head	m	136
Maximum Discharge	m^3/s	26
Maximum Output	MW	30
Transmission Line (Churasaku-Taiho)	-	66 kV, 1 cct Total Length 18 km (Approx.)

The plant includes construction of an excavated type reservoir (approximately 250 x 250 m) on a table and of the elevation around 150 m approximately 600 m from the sea shore.

Maximum discharge of 26 m^3/s is drawn by an intake at the bottom of the reservoir, and conducted through a penstock of length approximately 340 m to a powerhouse provided approximately 150 m underground. After generation of a maximum output of 30 MW with the effective head of 136 m, the water goes through a tailrace tunnel of a length approximately 200 m and discharges into the sea from an outlet. During pump-up, seawater is pumped up in reverse from the sea to the upper regulating reservoir.

For transmitting the power generated and receiving the power for pump-up, a transmission line of 66 kV will be newly constructed over a distance of approximately 18 km for connection with Taiho Substation of Okinawa Electric Power Co., Inc.

After construction on the plant is completed, it will be operated for five years, during which time the plant will be checked for metal corrosion (to the turbine and other components), marine life growth (shellfish etc.), and environmental monitoring data will be collected. Total verification will be obtained for the use of seawater pumped-storage technology for electric power generation.

DESIGN OF FACILITIES

Upper Reservoir

Rubber sheet lining is to be provided as the sealing medium for the regulating reservoir, to prevent seawater from seeping into the surrounding ground. However, in case any leakage does occur, leakage detection and water collection systems are to be provided in a gallery beneath the reservoir.

The crest of the reservoir is to have a free-board of 2 m above, the high water level in view of the wave caused by strong winds (maximum wind speed 50 m/s during typhoons).

Furthermore, a 1 m high parapet is to be provided as a measure to prevent seawater spray.

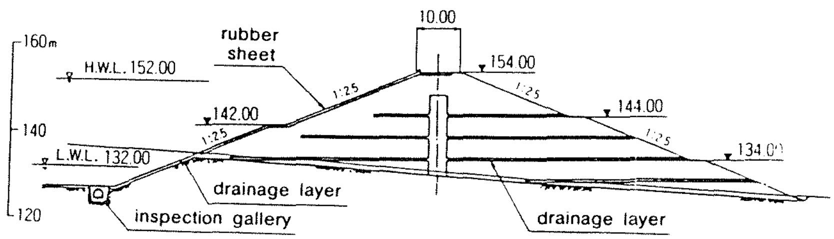


Figure 4 Typical Section of Dam

Waterway

To prevent seepage of seawater into the groundwater, the penstock is to have an inner lining mainly of fiberglass reinforced plastic pipe; steel pipe will also be used in place (at bends).

To minimize growth of marine organisms in the waterway, a special coating around the parts consisting of steel pipes will be provided. This coating will also serve to improve corrosion protection.

The tailrace is to be concrete-lined, but a special coating will be provided at the inner surface of the concrete to minimize adhesion of marine organisms.

Powerhouse

The powerhouse is to be an underground type provided approximately 150 m below the ground surface. The underground powerhouse cavern is to be 17 m in width, 32 m in height, and 41 m in length. The volume of excavation for the cavern is approximately 18,000 m^2.

For construction of the powerhouse, delivery of equipment such as the generator-motor, and for installation of an elevator and stairway, a vertical shaft of height 153 m and inside cross section 7 m x 7.6 m is to be provided adjacent to the powerhouse.

Intake and Outlet

Precast concrete breakwaters are to be set in the surroundings of the outlet, to minimize changes in flow conditions of the sea area and to reduce deep water wave reflection.

To minimize the effect on coral as much as possible, the approach flow velocity of the outlet screen is to be less than 1 m/s.

It was feared there could be adverse effects on the surrounding sea area as a result of changes in water temperature and water quality, depending on the length of time that seawater is retained in the upper reservoir. However a study showed it was considered that the changes would be very small.

Electrical Facilities

For the parts of the pump turbine requiring high strength such as runners and guide vanes, it is planned to adopt a modified variety of austenite type stainless steel judged to be optimum among stainless steels from the standpoints of strength, corrosion resistance, and forgoing technology. Regarding other members, the designs are to be for preventing rises in equipment cost by means such as the combined use of durable paint and electric corrosion protection.

IMPACT ON VEGETATION AROUND THE UPPER RESERVOIR

Plants with strong resistance to salt were found to grow thickly in the vicinity of the upper reservoir.

As a result of studies carried out concerning the salt spray from the upper reservoir, it was predicted that there would be no effect on vegetation in view of the small surface area of the plant reservoir. During investigations concerning salt damage to sugar cane (which is the main agricultural crop of Okinawa), it was found that wind damage during typhoons is a considerably more serious problem in Okinawa Island than salt damage.

To confirm these predictions and assessments, some observations and measurements of groundwater levels, salt concentrations in soil, and salt spray quantities, are to be carried out in the monitoring process before and after construction.

ENVIRONMENTAL PROTECTION

As a result of environmental assessment, it is believed that the environmental impact of the plant will be minimal by taking following measures.

1. The total surface area within the upper reservoir will be covered with a rubber sheet to protect the reservoir from seawater seepage.

2. The waterway will be lined with FRP (Fiber glass Rainforced Plastic) to prevent corrosion and to protect from seawater seepage.

3. Special emphasis will be made on water velocity and the outlet structure to protect coral and marine life from the inflow and outflow.

4. The tunnel and powerhouse will be located underground to ensure the existing pleasant natural scenery is retained.

Maximum emphasis and care will be taken to ensure minimal disturbance of the natural habitat and wildlife. Emphasis will also be place on minimizing the effect of noise, vibration, and water discoloration.

WHAT IS A VARIABLE SPEED PUMPED-STORAGE SYSTEM?

This system can control pumping input and generating output by changing the rotational speed of motor/generator. Characteristics of a variable speed system are:

1. An AFC (Automatic Frequency Control) pumping operation becomes possible because of variable pumping input.

2. A variable speed system can be operated at the optimum speed of a pump-turbine. Therefore the system efficiency is much improved. and operating range can be expanded.

3. A variable speed system can control effective power rapidly to improve power system stability.

TEST DEMONSTRATION

The following items will be tested:

1. Tolerance of materials against corrosion, salinity, etc.

2. Observation of marine growth adhering to materials and a determination of measures to protect the materials.

3. Effects of seawater spray on the surrounding environment.

4. Evaluation of the variable speed pumped-storage system.

5. Evaluation of the seawater pumped-storage power plant operation interconnected with the power system.

OPERATION OF A PUMPED STORAGE POWER PLANT

Electrical consumption varies greatly through the day. Consumption during late night and early morning is approximately 50% less than during daylight hours. However nuclear and thermal power plants are more efficient and economical if operated at a constant rate.

A pumped-storage power generation system can increase system efficiency since during times of low electrical usage, power from existing nuclear and thermal power plants can be used to drive turbines to pump water into the upper reservoir.

During daylight hours when high usage occurs, peak power can be generated by releasing water from the upper reservoir, through the pumped-storage power plant, on out to the lower reservoir. Significant savings can be realized using this technology.

Pumped-storage power generation is a very efficient method of saving electrical power during off peak times when an excess can be produced. Furthermore it is essential to develop these efficient power plants that rely on using water resources as renewable energy.

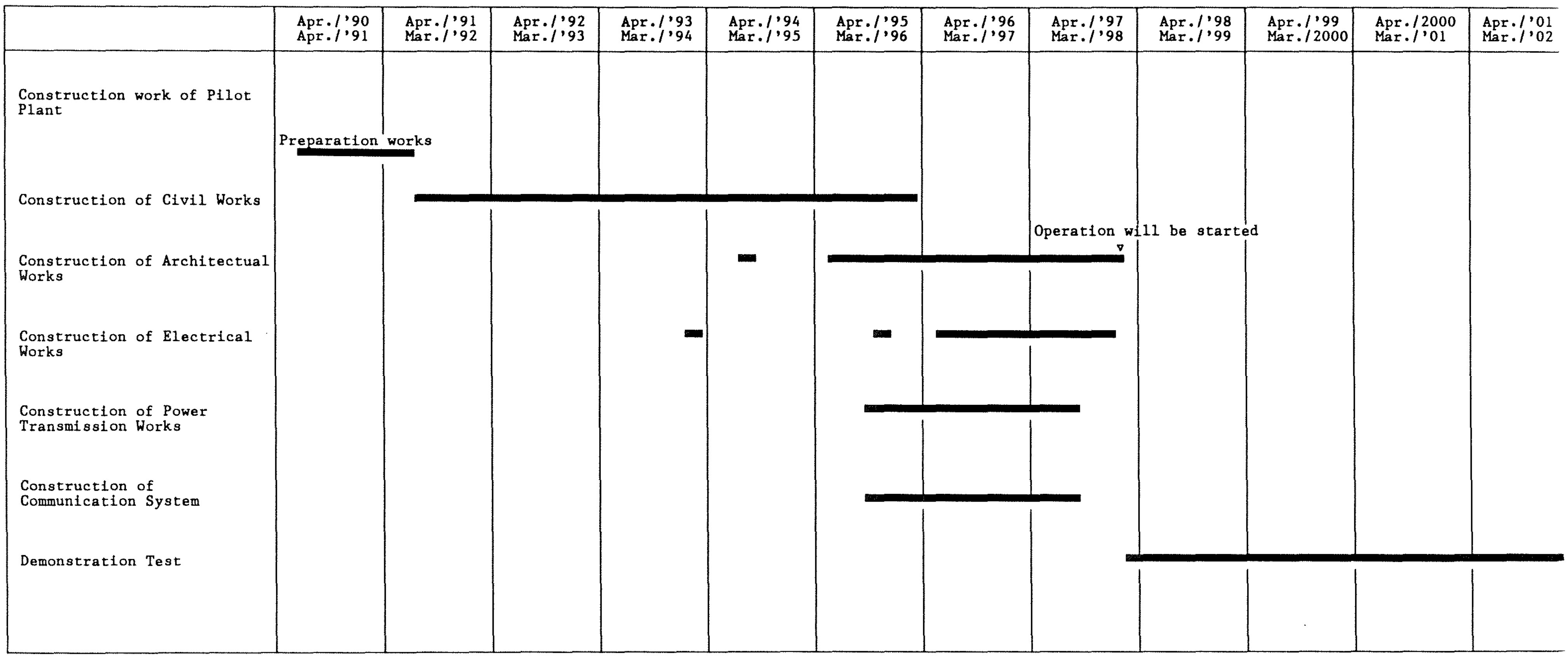
This project is a demonstration test of a seawater pumped-storage power plant sponsored by the MITI, and is undertaken by EPDC.

WORK SCHEDULE

The construction started in July, 1991 has progressed 60% of the total civil work as of April, 1993.

After construction on the plant is completed, test operation is to be carried out for a five-year period, during that period investigations will be made on corrosion protection effects (concerning metallic materials for the waterway and turbine), and the adhesion of marine organism. Also, environmental monitoring data will be collected for establishment of a comprehensive seawater pumped-storage power generation system.

Work Schedule



Progress of the Construction Works of the Seawater Pilot Power Plant on Okinawa

(progress of civil works up to end of the year 1993)

Item	Works	Progress
Reservoir	Excavation Embankment	83% 71%
Intake structure	Excavation Concrete	19% 0%
Penstock L = 314 m (ϕ 2.4 m)	Excavation Concrete	100% 100%
Drainage tunnel L = 187 m	Excavation Concrete	91% 65%
Disposal area	Excavation	-
Access road to dam L = 140 m	Excavation	-
Access road to powerhouse L = 380 m	Excavation	100%
Access shaft to powerhouse L = 148 m	Excavation Concrete	100% 11%
Powerhouse	Excavation Concrete	100% 18%
Draft gate hall	Excavation Concrete	99% 0%
Access tunnel to outlet structure L = 180 m	Excavation Concrete	100% 98%
Switchyard	Excavation Concrete	- -
Tailrace L = 205 m (ϕ 2.7 m)	Excavation Concrete	100% 0%
Outlet structure	Excavation Concrete Rubblemound Breakwater	78% 99% 60%

Total progress of civil works : approximately 65%

Total progress : approximately 35.4%